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The Effect of Diets on Milk Production and Composition, and on Lactation Curves in Pastured Dairy Goats

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ABSTRACT

A 2-yr study investigated effects of different levels of concentrate supplementation on milk production, composition, and lactation curves in pastured dairy goats. For both years, 44 Alpine goats (*Capra hircus*; 55 ± 11 kg body weight) were randomly allocated to 4 groups. Animals were supplemented with 0.66 (treatments A and B), 0.33 (treatment C), or 0 kg of concentrate (treatment D) per kg of milk over 1.5 kg/d. Mixed vegetative forages were rotationally grazed by the goats (treatments B, C, and D), except that treatment A was confined and fed alfalfa hay. Individual milk production was recorded daily, and milk samples were collected once every 2 wk for the 7-mo period (March to September) and analyzed for fat, protein, lactose, urea-N, nonesterified fatty acids, and allantoin (second year only). Milk yield and composition varied among dietary treatments, with some measures affected by year. Average daily milk yield was lowest for treatment D. The increased level of concentrate supplementation in treatment A led to 22% greater milk yield compared with treatment D. Milk production increased by 1.7 and 0.9 kg for each additional kilogram of concentrate fed per day during the first and second years, respectively. Average peak yield, time of peak yield, and persistency were lower for treatment D than for other treatments. The percentage of milk fat was lower for treatment D than for other treatments. Concentration of milk protein was greater for treatments A and B during the first year, and was higher for treatment C than for other treatments during the second year. Average milk lactose concentration was higher for treatments B and C than for other treatments. However, milk urea-N concentration in treatment A was higher than other treatments. Milk allantoin, used to estimate microbial proteins synthesis, was 20 to 25% greater for treatment A than for other treatments. Averaged across year, plasma urea-N and nonesterified fatty acids concentration were lowest for treatment B. Average organic matter intake was similar among treatments during both years. Ratios of acetate and propionate concentrations for treatment A were lowest among treatments. In conclusion, milk production and composition were affected by the feeding treatment and year. Increased level of nutrition lead to an increase in daily milk yield, peak yield, time of peak yield, and persistency compared with treatment D. Alpine dairy goats grazing on fresh forages without concentrate supplementation can produce milk inexpensively, and response to concentrate supplementation is greater for low quality pasture.
(**Key words:** dairy goat, lactation curve, milk composition, forage)

Abbreviation key: A/P ratio = acetate to propionate molar ratio, **BWG** = daily BW gain, **IVOMD** = in vitro OM digestibility, **ME** = metabolizable energy, **OMI** = OM intake.

INTRODUCTION

Optimal feeding programs for grazing Alpine dairy goats and their lactation curves are not well established. Considerable research, however, has been conducted over the years on concentrate supplementation level at pasture for dairy cows (O'Brien et al., 1999; Bargo et al., 2003). Research on the comparative composition of proteins and their components in the milk of goats and cows have been reviewed (Haenlein, 2004), documenting many unique differences between the 2 species, and showing a wide diversity due to genetics of different breeds within each species, influences of stage of lactation, feeding, climate, and subclinical mastitis.

Dietary characteristics influence milk yield and milk composition of dairy goats, as well as daily BW gain (**BWG**). Previous studies have shown a positive correlation between both the amount and the concentration of metabolizable energy (**ME**) and either milk protein content or protein yield (Sporndly, 1989). This latter response may be altered by the synchrony of the degradation rate of carbohydrate and protein in the diet (Cas-

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per et al., 1990). Goetsch et al. (2001) reported that high levels of concentrate diet (65%) depressed milk yield in does in late lactation compared with a 50% concentrate diet. Conversely, these results did not support similar influences of dietary concentrate and energy levels with dairy cows (NRC, 2001). High levels of concentrate diet that depress milk production during late lactation might not be true for efficiency of energy use and milk production over the entire lactation period in Alpine dairy goats. Influences in nutrient demand in grazing dairy goats on long-term milk production responses to diets varying in properties such as levels of concentrate and forage have not been extensively studied.

High level of concentrate diets influenced plasma and mammary gland metabolites in dairy cows (Vandehaar et al., 1999). However, the effect of different levels of concentrate diets on rumen and plasma metabolites during the lactation period in dairy goats is unclear. The objectives of this experiment were to determine 1) the effect of dietary concentrate levels during lactation period on milk production, composition, and BWG of Alpine dairy goats, and 2) subsequent metabolites of rumen and blood plasma in pastured dairy goats.

MATERIALS AND METHODS

Forages

This 2-yr experiment was conducted at the E (Kika) de la Garza American Institute for Goat Research (Langston University, Langston, OK) from March 10, 2000 to September 30, 2001. Goats rotationally grazed 8 mixed vegetative forages (0.75-ha paddocks). The paddocks contained wheat (*Triticum aestivum* L.), berseem clover (*Trifolium alexandrinum* L.), wheat/ryegrass (*Lolium multiflorum*), sudangrass (*Sorghum bicolor*), and crabgrass (*Digitaria ciliaris*). Residence time in each paddock varied but averaged 7 d and was adjusted to maintain minimum daily forage allowances of 2 to 4 kg of DM/d. Total grazing days were calculated as described by Min et al. (1999). Forage was managed to provide high quality vegetation at all times.

Herbage mass was measured before and after grazing, and samples of forage on offer (cut to ground level) were collected. Samples of diet selected (hand-plucked) were obtained as described by Min et al. (1999). Hand-plucked samples were used to estimate in vitro OM digestibility (**IVOMD**) for calculation of OM intake (**OMI**). Concentrate feed offered and orts were weighed, and samples from both feed on offer and orts were collected at 5-d intervals and composited for each month.

Animals and Experimental Procedures

Each year, 44 mixed-age Alpine does (*Capra hircus*; 55 ± 11 kg BW) were blocked by lactation number and previous lactation level and randomly allocated to 4 treatments. Animals were fed their supplements individually using Calan head gates (American Calan, Inc., Northwood, NH); therefore, animals were experimental units. Does kidded from March to April. Does were supplemented with 0.66 (treatments A and B), 0.33 (treatment C), and 0 kg of concentrate (treatment D) per kg of milk production greater than 1.5 kg/d. Does were fed an additional 0.5 kg of concentrate (treatments A, B, and C) for the first 8 wk of lactation as lead feeding. All goats were rotationally grazed on mixed vegetative forages except for treatment A (confined and fed alfalfa hay).

Goats were weighed and drenched with anthelmintic (Panacur; Mar Vista Animal Medical Center, Los Angeles, CA) before the experiment commenced and then were drenched again when fecal egg counts exceeded 800 eggs/g of feces during the lactation period. Samples for fecal egg counts were obtained once monthly and determined using a modification of the McMaster technique (Stafford et al., 1994).

The animals were milked twice daily at 0700 and 1600 h. Milk yield was recorded daily, and milk samples from both a.m. and p.m. milking were collected once every 2 wk and analyzed for fat, protein, lactose (infrared spectroscopy, Dairylab II; Foss Food Technology, Eden Prairie, MN), and milk urea-N (Technicon Instruments, Tarrytown, NY). Allantoin concentration in milk was measured by HPLC (Hewlett Packard 1090, Amino Quant, AT3100, Palo Alto, CA) as an estimate of microbial protein synthesis (Puchala et al., 1992). Allantoin was measured only in the first year.

The OMI was measured during 3 lactation periods (May, June, and September) using slow-release chromium capsules (Cr_2O_3 matrix; Nufarm, Auckland, New Zealand) according to the method described by Min et al. (2001). Six animals per treatment were used to estimate OMI. Six rumen-fistulated wether goats were grazed together with experimental animals on each forage for 27 d to measure the chromium release rate of capsules suspended in the rumen. Measurements of chromium release started on d 5 after chromium capsule insertion, and proceeded at 2 d intervals until d 27.

Samples of rumen fluid (via stomach tube) and blood (via jugular venipuncture) were collected at monthly intervals from 6 animals per treatment. Rumen fluid samples were analyzed for pH, VFA (Goetsch and Galyean, 1983), and ammonia-N (Chaney and Marbach, 1962). Plasma was harvested by centrifugation (1500 $\times g$) and stored at –20°C for analyses of glucose, urea-

Table 1. Chemical composition (% DM) and in vitro OM digestibility (% DM) of pasture and concentrate fed and feed refusals by goats.

			Pasture		Supplementation			
Item	Year	n	Pregrazing	Postgrazing	Concentrate[1]	Alfalfa hay	Refusals	SEM
DM	2000	14	92.6	92.0	90.8	91.2	85.9	2.71
	2001	14	91.3	93.2	89.5	93.5	89.2	0.62
OM	2000	14	91.8	92.7	94.7	86.2	92.5	3.70
	2001	14	87.1	85.5	86.1	87.1	84.3	2.13
CP	2000	14	11.1	8.5	11.2	13.9	13.3	0.90
	2001	14	13.5	9.7	11.7	16.5	13.7	1.01
ADF	2000	14	30.5	30.7	6.3	37.8	12.6	2.08
	2002	14	29.4	32.5	6.5	37.7	21.6	2.04
NDF	2000	14	52.4	53.8	11.1	46.4	16.5	2.18
	2001	14	26.4	45.8	13.8	39.7	28.8	2.04
IVOMD[2]	2000	14	71.1	75.2	92.8	75.8	89.5	2.10
	2001	14	85.4	84.3	94.4	71.7	82.3	1.48

[1]Concentrate composition: 74.5% rolled corn, 5% whole cottonseed, 16% soybean meal, 2% sodium bicarbonate, 0.2% dicalcium phosphate, 1.6% limestone with trace minerals, and vitamins A, D, and E.

[2]IVOMD = In vitro OM digestibility.

N (Technicon Instruments), and NEFA (Sahlu et al., 1992).

Sample Analyses

Feed, orts, forages, and feces were oven dried (60°C) and ground to pass a 1.0-mm mesh sieve for most laboratory analysis. The OM was determined by ashing at 550°C in a muffle furnace for 12 h. Crude protein was measured by the Kjeldahl method (AOAC, 1975). The NDF, ADF, and IVOMD were determined using the filter bag technique (ANKOM Technology Corp., Fairport, NY).

Statistical Analyses

Forage chemical composition, milk production and composition, BW, and rumen and blood plasma metabolites were analyzed by ANOVA by the GLM procedures of SAS (SAS Institute, 1985) using the following statistical model:

$$Y_{ijk} = \mu + T_i + Y_j + TY_{ij} + e_{ij}$$

where Y_{ijk} = observation; μ = overall mean for each parameter; T_i = effect of diet; Y_j = effect of year; TY_{ij} = interaction between diet and year; and e_{ij} = random error, used to test diet, year, and diet × year interaction.

Treatment means were separated by least significant differences when overall *F*-values were significant ($P < 0.05$). Main effect means for dietary treatment and year were presented in tables. Milk production from the first 2 wk of lactation was use as a covariate for statistical analysis of milk yield.

Peak milk production, date of peak milk production and persistency were calculated using parameters obtained by nonlinear regression of the lactation curve using Gipson and Grossman's (1990) gamma model (SAS Institute, 1985). The relationships between milk allantoin, milk yield, DMI, milk urea-N, and plasma urea-N contents were examined by regression analysis. Milk production per kilogram of concentrate was analyzed by regression analysis of animals on treatments A, B, and C. The relationships between milk yield and concentrate DMI were further examined by heterogeneity regression analysis between years.

RESULTS

Forage Yield, Chemical Composition, and IVOMD

Chemical composition and IVOMD of forage and concentrate feed during the 2-yr are presented in Table 1 and Figure 1. Pasture quality was consistently high from April to September for the second year, but forage quality was lower for the first year, as evidenced by higher NDF and lower IVOMD. The OM, ADF, and NDF in forages (pregrazing) were higher for the first year than for the second year, but CP (14 vs. 11%) and IVOMD (85 vs. 71%) were higher for the second year than for the first year, presumably due to the higher quality of forage offered to dairy goats during the second year of study. Seasonal variations in forage NDF, CP, and IVOMD are presented in Figure 1.

OMI and BWG

Results of BW, BWG, and OMI are presented in Table 2. Average BW was lower ($P < 0.05$) for treatment C in the first year than for the other treatments, whereas BW was lower for treatments B and C in the second year (treatment by year interactions; $P < 0.05$). Daily

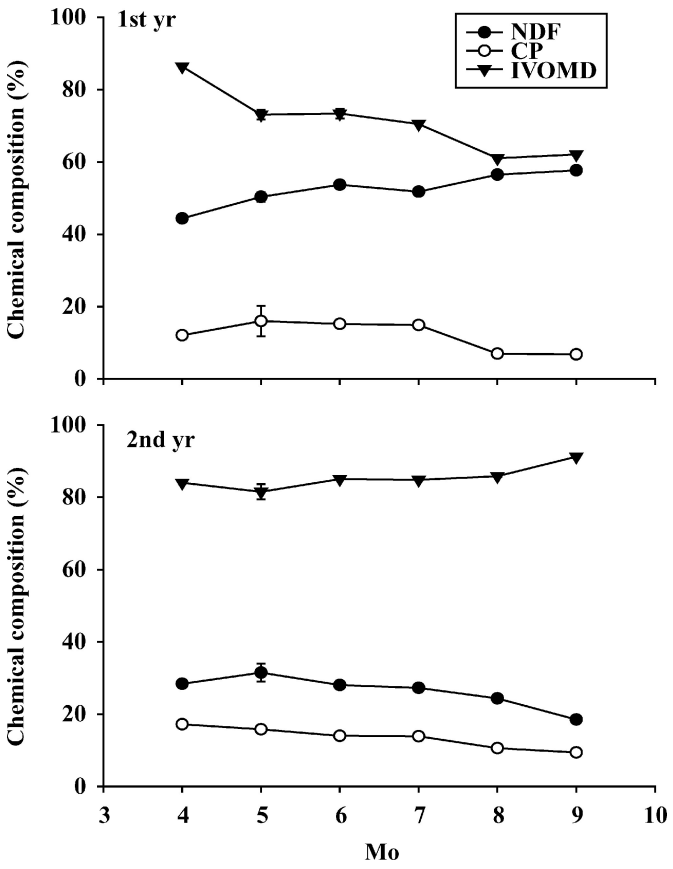

Figure 1. Mean chemical composition of in vitro OM digestibility (IVOMD), NDF, and CP of pasture for grazing dairy goats during the first year and the second year. Results are the least square mean values of each month and vertical error bars represent standard error of the mean.

BWG was substantially higher ($P < 0.01$) for treatment B in the first year compared with other treatments, whereas, BWG means were similar for all treatments during the second year. The higher gains from treatment B the first year cannot be readily explained.

Average OMI were similar among treatment group during both years. The OMI in treatment D was significantly ($P < 0.05$) lower than that of goats in treatments A and B during the first year, but OMI in treatment A was lower ($P < 0.05$) than that of other treatments during the second year.

Rumen and Plasma Metabolites

Average acetate concentrate was highest for treatment A during the second year (Table 3). Acetate concentration, however, was lowest for treatment D during the second year, with a treatment by year interaction ($P < 0.05$). Average propionate concentration was highest for treatment A, with a treatment by year interaction ($P < 0.01$). Average isobutyrate and butyrate were similar among treatments for the 2 yr, but there were treatment by year interactions ($P < 0.05$). Isovalerate concentration was similar among treatments, but valerate concentration was lowest for treatment D. Total average VFA concentration was similar among treatments during the 2 yr. Total VFA concentration in rumen fluid was higher ($P < 0.05$) for treatment A than for other treatments during the first year, but was highest for treatment B the second year, with a treatment by year interaction ($P < 0.01$). Acetate and propionate molar ratios (**A/P ratio**) for treatment A were lowest among treatments ($P < 0.05$).

Rumen pH (Table 4) decreased with increasing concentrate supplementation ($P < 0.01$) in both years. Average ruminal ammonia concentration was higher ($P < 0.001$) for treatments A and B than for treatments C and D during both years. Ruminal ammonia concentration was higher ($P < 0.01$) for the second year than for the first year, consistent with the higher levels of CP

Table 2. Animal BW, BW gain (BWG), and OM intake (OMI) in dairy goats fed 4 levels of concentrate supplements.

			Treatment[1]						
Item	Year	n	A	B	C	D	SEM	*P*	Treatment × year interaction
BW (kg)	2000	11	54.5[a]	52.9[a]	51.6[b]	55.7[a]	0.51	0.05	
	2001	11	53.2[a]	49.3[b]	50.0[b]	52.1[a]	0.57	0.05	
	Mean		53.9[a]	51.1[b]	50.8[b]	53.9[a]	0.61	0.05	0.05
BWG (g/d)	2000	11	19.3[b]	56.3[a]	6.7[b]	15.3[b]	13.5	0.01	
	2001	11	43.9[a]	28.3[a]	22.4[a]	37.7[a]	14.2	NS	
	Mean		31.6[a]	42.3[a]	14.6[b]	26.5[a]	9.8	0.05	NS
OMI (kg/d)	2000	9	2.0[a]	1.8[a]	1.4[b]	1.2[bc]	0.16	0.05	
	2001	9	1.7[b]	2.1[a]	2.1[a]	2.5[a]	0.11	0.05	
	Mean		1.8	1.9	1.8	1.9	0.19	NS	0.05

[a,b,c]Means within a treatment or mean grouping without a common superscript letter differ ($P < 0.05$).

[1]Treatments A, B, C, and D were supplemented with 0.66 (treatments A and B), 0.33 (treatment C), and 0 kg of concentrate (treatment D) per kg of milk over 1.5 kg/d, respectively. Mixed vegetative forages were rotationally grazed by the dairy goats, except for treatment A (confined and fed alfalfa hay).

Table 3. Ruminal VFA contents in goats fed 4 different levels of concentrate supplements.

Item	Year	n	Treatment[1] A	B	C	D	SEM	*P*	Treatment × year interaction
VFA (m*M*)									
Acetate	2000	60	43.4[a]	33.1[b]	29.8[b]	34.4[b]	2.16	0.01	
	2001	60	40.0[a]	45.1[a]	40.6[a]	35.1[b]	2.65	0.05	
	Mean		41.7[a]	39.1[ab]	35.2[b]	34.8[b]	1.82	0.05	0.05
Propionate	2000	60	14.2[ab]	8.9[c]	8.8[c]	7.0[c]	0.83	0.01	
	2001	60	15.3[a]	17.1[a]	11.5[b]	10.1[c]	1.09	0.01	
	Mean		14.7[a]	13.0[b]	10.2[bc]	8.5[c]	0.64	0.01	0.01
Isobutyrate	2000	60	0.66[b]	0.68[b]	0.73[a]	0.66[b]	0.10	0.05	
	2001	60	1.03[a]	0.79[a]	0.84[a]	0.88[a]	0.13	0.05	
	Mean		0.85	0.74	0.78	0.77	0.08	NS	0.05
Butyrate	2000	60	9.5[b]	7.3[c]	6.1[c]	5.3[c]	0.58	0.01	
	2001	60	9.6[b]	11.8[a]	10.3[a]	10.2[a]	0.75	0.01	
	Mean		9.5	9.5	8.2	7.4	0.51	0.01	0.05
Isovalerate	2000	60	0.9	1.0	0.8	0.8	0.12	NS	
	2001	60	1.5	1.3	1.5	1.5	0.15	NS	
	Mean		1.2	1.2	1.1	1.2	0.09	NS	NS
Valerate	2000	60	0.9	0.9	0.7	0.5	0.14	NS	
	2001	60	1.2	1.2	1.0	1.0	0.18	NS	
	Mean		1.1[a]	1.1[a]	0.9[a]	0.7[b]	0.12	0.01	NS
Total VFA	2000	60	69.5[a]	48.5[c]	46.0[c]	49.5[c]	3.56	0.01	
	2001	60	67.6[b]	77.3[a]	65.7[b]	58.8[b]	4.28	0.01	
	Mean		68.5	62.9	55.9	54.2	3.55	0.01	0.01
A/P ratio[2]	2000	60	3.4[b]	5.2[a]	4.0[a]	5.2[a]	0.54	0.05	
	2001	60	3.1	3.0	3.9	3.8	0.68	NS	
	Mean		3.2[b]	4.1[a]	4.0[a]	4.5[a]	0.43	0.05	NS

[a,b,c]Means within a treatment or mean grouping without a common superscript letter differ ($P < 0.05$).

[1]Treatments A, B, C and D were supplemented with 0.66 (treatments A and B), 0.33 (treatment C), and 0 kg of concentrate (treatment D) per kg of milk over 1.5 kg/d. Mixed vegetative forages were rotationally grazed by the dairy goats except for treatment A (confined and fed alfalfa hay).

[2]A/P ratio = Acetate to propionate molar ratio.

Table 4. Ruminal pH, concentration of ammonia-N in the rumen, plasma parameters, and milk allantoin content (mg/L) in dairy goats fed 4 different levels of concentrate supplements.

Item	Year	n	Treatment[1] A	B	C	D	SEM	*P*	Treatment × year interaction
Ruminal pH	2000	60	6.3[c]	6.5[b]	6.7[a]	6.9[a]	0.08	0.01	
	2001	60	6.4[c]	6.6[b]	6.7[b]	6.9[a]	0.05	0.01	
	Mean		6.4[c]	6.6[b]	6.7[b]	6.9[a]	0.05	0.01	0.05
Ruminal ammonia (mg of N/L)	2000	60	279[c]	260[c]	304[c]	293[c]	24.7	NS	
	2001	60	634[a]	580[a]	416[b]	450[b]	25.6	0.01	
	Mean		457[a]	425[a]	360[b]	372[b]	34.5	0.05	0.05
Plasma (mg/dL)									
Glucose	2000	60	32.1[c]	37.7[c]	37.7[c]	31.8[c]	1.07		
	2001	60	56.1[a]	52.9[a]	52.1[ab]	48.4[b]	0.76		
	Mean		44.1[a]	45.4[a]	44.9[a]	40.1[b]	1.32	0.05	0.05
Urea-N	2000	60	20.1	15.8	18.4	24.3	1.07	NS	
	2001	60	17.6	14.0	17.1	19.8	0.76	NS	
	Mean		18.8[a]	14.9[b]	17.8[ab]	22.0[a]	1.31	0.05	NS
NEFA (μEq/L)	2000	60	362	311	338	403	15.03	NS	
	2001	60	243	244	312	321	18.03	NS	
	Mean		302[a]	278[b]	325[a]	362[a]	23.5	0.05	NS
Milk allantoin[2] (mg/L)	2000		17.4[a]	13.4[b]	14.0[b]	13.0[b]	1.35	0.05	

[a,b,c]Means within a treatment or mean grouping without a common superscript letter differ ($P < 0.05$).

[1]Treatments A, B, C and D were supplemented with 0.66 (treatments A and B), 0.33 (treatment C), and 0 kg concentrate (treatment D) per kg of milk over 1.5 kg/d. Mixed vegetative forages were rotationally grazed by the dairy goats except for treatment A (confined and fed alfalfa hay).

[2]Microbial protein synthesis was estimated by allantoin concentrations (mg/L) in milk.

Table 5. Milk production and ANOVA for each lactation curve in goats fed 4 levels of concentrate supplements.

Item	Year	n	Treatment[1] A	B	C	D	SEM	*P*	Treatment × year interaction
Milk yield (kg/d)									
	2000	11	3.59[a]	2.95[a]	2.48[b]	2.09[b]	0.09	0.05	
	2001	11	4.08[a]	4.12[a]	4.27[a]	3.77[a]	0.11	NS	
	Mean		3.84[a]	3.45[b]	3.50[b]	2.98[c]	0.09	0.01	0.01
Peak yield (kg of milk)[2]									
	2000	11	4.0	3.7	3.5	3.3	0.13	NS	
	2001	11	5.5	4.7	5.2	4.6	0.16	NS	
	Mean		4.7[a]	4.2[a]	4.3[a]	3.9[b]	0.20	0.01	NS
Time of peak yield[2] (days from kidding)									
	2000	11	44	32	32	22	2.11	NS	
	2001	11	41	37	41	36	2.46	NS	
	Mean		43[a]	35[a]	36[a]	29[b]	3.22	0.01	NS
Persistency[2]									
	2000	11	6.5	6.2	6.1	5.6	0.07	NS	
	2001	11	6.3	6.3	6.4	6.2	0.08	NS	
	Mean		6.4[a]	6.2[a]	6.2[a]	5.9[b]	0.11	0.01	NS

[a,b,c]Means within a treatment or mean grouping without a common superscript letter differ ($P < 0.05$). Milk production from the first 2 wk was use as a covariate.

[1]Treatments A, B, C, and D were supplemented with 0.66 (treatments A and B), 0.33 (treatment C), and 0 kg of concentrate (treatment D) per kg of milk over 1.5 kg/d. Mixed vegetative forages were rotationally grazed by the dairy goats except for treatment A (confined and fed alfalfa hay).

[2]Calculated from parameters of Gipson and Grossman's (1990) gamma lactational model.

in pastures (and alfalfa hay) the second year than the first year. There was a treatment by year interaction ($P < 0.05$) in that all ammonia levels were similar the first year, but were greater for treatments A and B in the second year.

Average concentration of plasma glucose was lowest ($P < 0.05$) for treatment D (Table 4). Plasma glucose was similar among treatments the first year, but lowest ($P < 0.05$) for treatment D the second year (treatment by year interaction; $P < 0.05$). Averaged across years, plasma urea-N and NEFA concentrations were lowest ($P < 0.05$) for treatment B.

Rumen Microbial Protein Synthesis

Allantoin, used to estimate microbial protein synthesis, was 20 to 25% greater for treatment A than for other treatments ($P < 0.05$; Table 4). Allantoin output in milk was correlated (r = 0.63; y = 22.2x – 20.7; $P < 0.001$) with daily milk yield (kg/d) over the 4 treatments (data not shown). Allantoin output in milk was correlated with milk production within each diet [r = 0.58 (y = 31.2x – 45; $P < 0.001$), 0.62 (y = 23.5x – 29; $P < 0.001$), 0.53 (y = 19.1x – 12.6; $P < 0.01$), and 0.44 (15x – 4.9; $P < 0.03$) in treatments A, B, C, and D, respectively]. Increased excretion of allantoin in milk was correlated (r = 0.44; y = 23.5x + 22.7; $P < 0.001$) to concentrate OMI, suggesting that concentrate provided additional energy for increased microbial protein production with conventional mixed forage diets. Milk allantoin was positively correlated (r = 0.48; y = 0.37x + 23.8; $P < 0.001$) with milk urea-N (mg/d), but was not correlated with plasma urea-N concentrations (r = 0.14; $P = 0.2$).

Milk Yield and Lactation Curves

Results of milk yield and composition are given in Tables 5 and 6 and Figures 2, 3, and 4. Average daily milk yield was lowest ($P < 0.01$) for treatment D during the 2 yr, with a treatment by year interaction, suggesting that high level of CP and IVOMD in the diets provided more milk yield among treatments. In the first year, daily milk yield from goats grazing forages in treatment D was lower ($P < 0.05$) than for goats receiving high levels of concentrate (treatments A and B; Table 5 and Figure 2). However, milk yield in the second year did not differ among treatments.

To further understand the effect of concentrate supplementation on milk production, the amount of concentrate DMI for the lactation for each animal was regressed against total milk production for the lactation (Figure 3). Milk production increased by 1.7 kg in the first year (r = 0.6; $P < 0.001$) and 0.9 kg in the second year (r = 0.58; $P < 0.001$) for each additional kilogram of concentrate fed. Overall comparisons by heterogeneity regression analysis showed that the 2 slopes between years were significantly different ($P < 0.01$).

Average peak milk yield was 12% lower ($P < 0.01$) for treatment D than for other treatment (Table 5). Time of peak yield (14 d) and persistency (9%) were higher for treatment A than for treatment D.

Table 6. Milk composition in goats fed 4 levels of concentrate supplements.

Item	Year	n	Treatment[1] A	B	C	D	SEM	*P*	Treatment × year interaction
Fat									
(%)	2000	54	3.2	3.1	3.1	3.0	0.05	NS	
	2001	58	3.1	3.0	3.0	2.9	0.05	NS	
	Mean		3.1[a]	3.1[a]	3.0[a]	2.9[b]	0.06	0.05	NS
(g/d)	2000	54	104	86	79	66	2.70	NS	
	2001	58	139	125	140	113	3.07	NS	
	Mean		121[a]	106[b]	109[b]	90[c]	4.09	0.01	NS
Protein									
(%)	2000	54	3.17[a]	3.07[a]	3.02[b]	2.80[b]	0.02	0.05	
	2001	58	2.99[b]	3.06[b]	3.10[a]	3.00[b]	0.02	0.05	
	Mean		3.08[a]	3.05[a]	3.08[a]	2.90[b]	0.03	0.05	0.01
(g/d)	2000	54	103	86	83	68	2.10	NS	
	2001	58	131	125	134	106	2.41	NS	
	Mean		117[a]	105[b]	109[b]	87[c]	3.18	0.01	NS
Lactose (%)									
	2000	54	4.16	4.24	4.19	4.00	0.02	NS	
	2001	58	4.06	4.14	4.11	3.98	0.02	NS	
	Mean		4.11[b]	4.19[a]	4.15[a]	3.99[c]	0.26	0.01	NS
Urea-N (mg/100 mL)									
	2000	54	21.3	16.6	17.7	17.5	0.53	NS	
	2001	58	22.0	18.5	19.5	20.0	0.57	NS	
	Mean		21.6[a]	17.6[b]	18.6[b]	18.8[b]	0.75	0.01	NS

[a,b,c]Means within a treatment or mean grouping without a common superscript letter differ ($P < 0.05$).

[1]Treatments A, B, C, and D were supplemented with 0.66 (treatments A and B), 0.33 (treatment C), and 0 kg of concentrate (treatment D) per kg of milk over 1.5 kg/d. Mixed vegetative forages were rotationally grazed by the dairy goats except for treatment A (confined and fed alfalfa hay).

Average milk yield peaked from April to June and then decreased ($P < 0.01$) as lactation progressed in both years (Figure 2). However, the influence of supplementation on peak milk yield was only observed in the first year of the study and modestly affected milk yield the second year.

Chemical Composition of Milk

Average percentages of fat and protein were lower ($P < 0.05$) for treatment D than for the other treatments (Table 6). Percentage of protein was higher for treatments A and B than for treatments C and D during the first year and was greatest for treatment C among treatments during the second year. Despite a dietary treatment by year interaction ($P < 0.01$) in milk protein concentration, mean milk protein concentration was similar among concentrate diets (treatments A, B, and C). Average lactose percentage was higher ($P < 0.05$) for treatments B and C than for other treatments. Fat and protein yields (g/d) were higher ($P < 0.01$) for treatment A than for treatments B and C, and treatment D was lower ($P < 0.05$) than treatments B and C. Milk urea-N concentration in treatment A was higher ($P < 0.05$) than other treatments.

Average milk concentrations of fat, protein, and lactose decreased ($P < 0.01$) as lactation progressed, except for fat in the second year and tended to increase toward the end of lactation (Figure 4).

DISCUSSION

Dietary Forage Quality and BWG

The value of a feed for animal production depends on its quality (i.e., digestible nutrient content) and level of voluntary feed intake in small ruminants (Deaville and Galbraith, 1992; Bosman et al., 1995). In the present study, average BW was similar between years, but daily BWG was considerably greater in the second year than the first year primarily because dietary forage quality (CP and IVOMD) was better the second year (Table 1). In addition, greater BWG in the second year may be partially related to improve feed efficiency (lower A/P ratios) for the second year (Table 3). These results are consistent with other studies where dietary CP and feed conversion efficiency (Black et al., 1987) are associated with higher BWG (Waghorn and Barry, 1987; Deaville and Galbraith, 1992).

Rumen and Plasma Metabolites

An interesting finding of this experiment is that A/P ratios in treatment D were 29% greater than in treatment A (Table 3). In a mathematical modeling study,

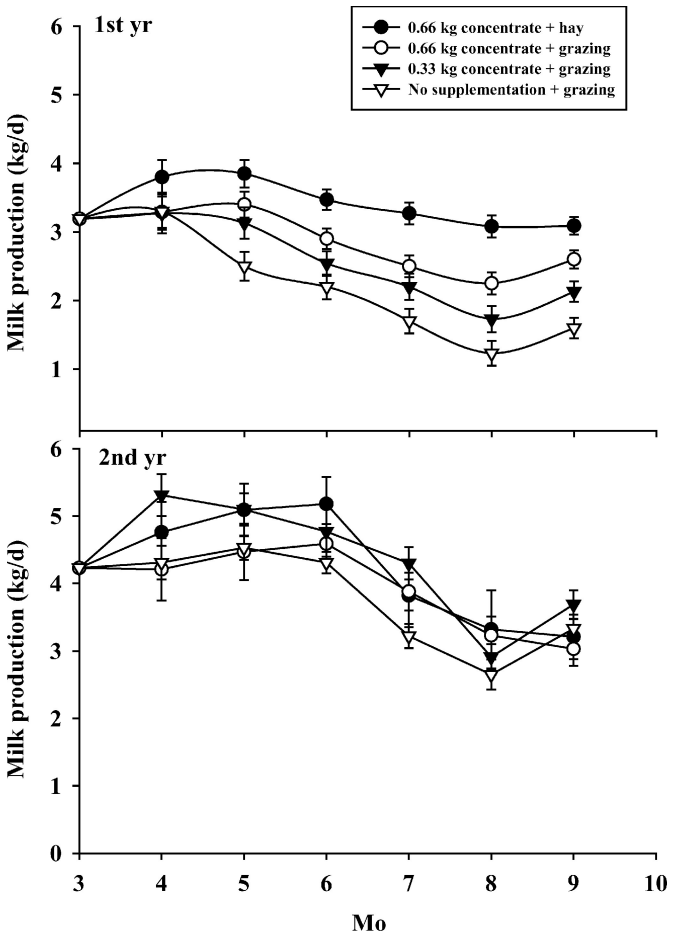

Figure 2. Mean monthly milk yield for grazing dairy goats during the first year (2000) and the second year (2001). Goats were supplemented with 0.66 kg of DM of concentrate mix and hay (treatment A), 0.66 kg/d of DM of concentrate and grazing (treatment B), 0.33 kg/d of DM of concentrate and grazing (treatment C), or no supplementation with grazing (treatment D). Results are the least square mean values of each month and vertical error bars represent SEM. Milk production from the first 2 wk was used as a covariate. $^{*}P < 0.05$, $^{**}P < 0.01$ during the first year (treatments A vs. D) and the second year (treatments C vs. B and D).

Black et al. (1987) showed that the efficiency of use of ME is very low in ruminants fed forage diets producing high A/P ratios, because of insufficient $NADPH_2$ being generated from glucose metabolism to allow all the acetate to be incorporated into body lipid. One explanation for the high milk production in group A in the present experiment may be related to reduced A/P ratios and to increased digestible energy intake. Higher A/P ratios are associated with lower BWG (Waghorn and Barry, 1987).

Satter and Slyter (1974) reported that rumen ammonia concentration below 50 mg of N/L, as would be found with animals fed a straw diet, limited the synthesis of microbial protein. In the present experiments, rumen ammonia concentration between 200 and 600 mg/L (Table 4) were not likely to limit rumen microbial protein synthesis. Most vegetative forages contain high concentrations of ME (11.5 MJ/kg of DM) of carbohydrate and total N (30 g/kg of DM; Waghorn and Barry, 1987). Rumen digestion of carbohydrate is efficient in such diets, but duodenal nonammonia nitrogen flow was only 65% of N consumed in sheep (MacRae and Ulyatt, 1974) due to excessive degradation of forage protein to ammonia by rumen microorganisms. In the present study, dairy goats that consumed high concentrate diets (treatments A and B) had higher rumen ammonia and milk urea-N concentrations than goats receiving no or little concentrate supplementation (treatments C and D) indicating that high concentrate levels increased ruminal ammonia and milk urea-N concentrations. This result is similar to other studies with dairy cows and goats (Ropstad et al., 1989; Brun-Bellut et al., 1990). Ruminal ammonia concentration was higher ($P < 0.01$) for the second year than for the first year, with treatment by year interactions ($P < 0.05$), suggesting that higher levels of CP in the diet in the second year provided additional protein for increased ruminal ammonia production.

In the present study, the higher concentrations of plasma glucose concentration for the second year may be the result of an improved supply of dietary CP, with the elevated rumen ammonia concentrations resulting from greater absorption of ammonia from the rumen or from the deamination of amino acids (glucogenesis) not used for body tissue growth. Deaville and Galbraith (1992) described a similar response on plasma glucose concentrations (91 and 96 mg/dL for low- and high-protein diets, respectively) in British Angora goats.

Ruminal Microbial Protein Synthesis

Microbial protein synthesis, as estimated by milk allantoin, was 23 to 25% higher for treatment A than for treatments B, C, and D, indicating that more microbial protein was synthesized in animals on treatment A than for the pasture animals. Van Soest et al. (1988) reported that the growth and efficiency of rumen microbial protein synthesis are mainly associated with the substrate, type of microbe, rumen outflow rate, and the amount of energy available to the microbe. However, the most important factor influencing microbial efficiency is the rumen outflow rate and energy available to microbes (Van Soest et al., 1988). Further research is needed to confirm the greater microbial protein synthesis on treatment A compared with other treatments.

Milk Yield, Composition, and Lactation Curves

Only a few dairy goat studies have modeled lactation curves using a mathematical function (Gipson and

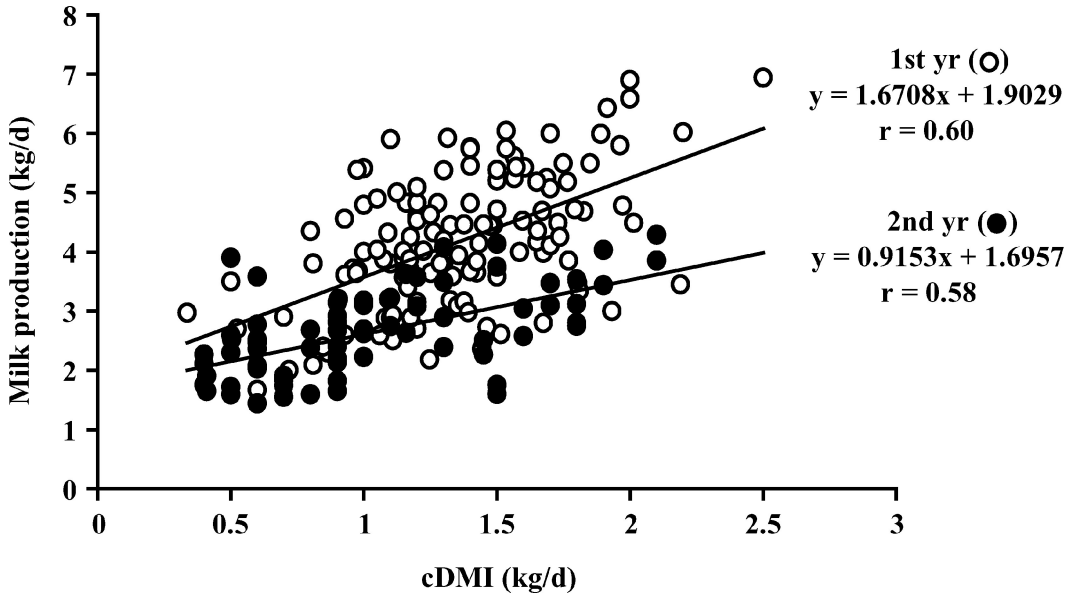

Figure 3. Influence of concentrate DM intake (cDMI; kg of DM/d) on milk yield (kg/d) of dairy goat during the first year and the second year. $^{**}P < 0.01$ between slopes.

Grossman, 1990). The total amount of milk produced during lactation is primarily determined by peak yield and persistency of lactation in dairy cows (McFadden, 1997). In dairy cattle, peak yield is the dominant factor, accounting for 66 to 80% of variance in total lactation yield, whereas persistency accounts for 8 to 12% of the variance (Gipson and Grossman, 1990; McFadden, 1997). Results from the present experiment indicate that grazing pasture and feeding different levels of concentrate were associated with variations in the production and composition of milk, and altered rumen and plasma metabolites. Increased level of nutrition (e.g., concentrate in treatment A) lead to an increase in daily milk yield (22%), peak yield (17%), time of peak yield (14 d), and persistency (8%) compared with treatment D. The longer it took to achieve peak yield, the greater the peak yield and total milk production. Animals on forage diets appeared to be more limited by nutrition, which resulted in earlier and lower peak production because they exhausted their body stores earlier. However, similar milk yield between high- (treatment B) and low- (treatment C) concentrate diets in grazing goats implies that high dietary concentrate levels at this time do not enhance average productivity as with dairy cows (NRC, 2001; Bargo et al., 2003). Morand-Fehr and Sauvant (1978) suggested that dairy goats differ from dairy cows in production responses to high dietary concentrate or ME levels. Reasons for differences between dairy goats and cows in milk production responses to various dietaries concentrate levels are unclear.

Greater milk yield for concentrate supplementation vs. nonsupplementation treatment in the present experiment suggests that diets as low in concentrate as 0.33 kg concentrate per kg of milk production provide adequate nutrients and energy for milk production and for subsequent longer time of peak lactation than for nonsupplemented diets. Alpine dairy goats grazing on fresh forage alone can produce milk inexpensively, but high-producing dairy goats need moderate levels of concentrate supplementation for economic success. However, the response to supplementation can be high if forage quality is low as in the first year and minimal if forage quality is high as in the second year.

From a processing standpoint, protein is the single most economically important milk component. Increased milk protein concentrations would benefit a number of important products (i.e., cheese, milk powder, evaporated milk, UHT milk) and this benefit would be greater if the casein concentration in milk were selectively increased (DePeters and Cant, 1992). There is strong evidence showing an increase in milk protein of 0.4 percentage units in dairy cows when the forage:concentrate ratio decreased from 40:60 to 10:90 (Sutton et al., 1980). The importance of the protein:energy ratio was confirmed by MacLeod et al. (1983), who found that dairy cows receiving a mixed feed supply with forage:concentrate ratios of 35:65 had higher (4 to 5%) milk protein content than the other groups (80:20, 65:35, and 50:50). The comparatively lower protein level in treatment D reflected the energy limitation of their diets and subsequent lower milk production. However,

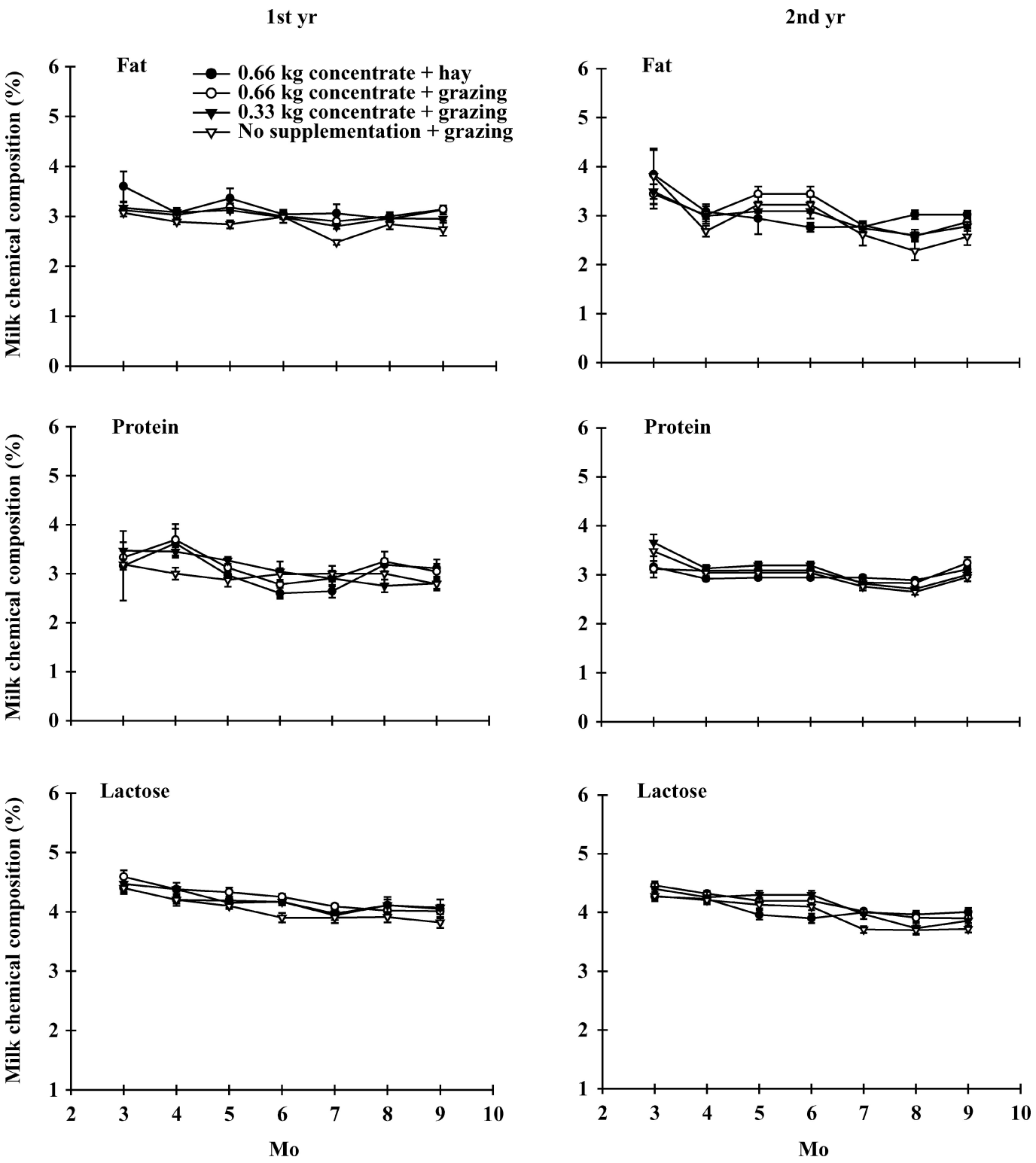

Figure 4. Mean monthly milk chemical composition for grazing dairy goats during the first and second year. Treatments A, B, C, and D were supplemented with 0.66 (A and B), 0.33 (C), and 0 (D) kg of concentrate per kg of milk over 1.5 kg/d. Mixed vegetative forages were rotationally grazed by the goats except for those in group A (confined and fed alfalfa hay). Vertical error bars represent SEM.

the present experiment shows that average milk protein concentration was similar among concentrate levels, and similar to findings from another study using Alpine dairy goats (Goetsch et al., 2001). However, these results do not support similar effects of dietary concentrate on milk protein concentrate in dairy cows (Sporndly, 1989). In addition, although fat supplementation in dairy cows and ewes often decreases the milk protein content and the associated coagulation properties, this negative effect should not exist in dairy goats (Chilliard et al., 2003).

Most protein requirement models assume that the sole requirement for protein is due to milk protein synthesis (NRC, 2001), whereas Dado et al. (1993) estimated that 76, 14, and 10% of the dietary protein was needed for milk protein, lactose, and fat production, respectively. This is important not only to maximize milk production, but also to increase protein production, and, hence, the manufacturing quality of the milk. Dairy cows grazing ad libitum had higher concentrations of milk protein and casein than animals grazing a restricted pasture allowance (O'Brien et al., 1999). The higher DMI and energy intake would presumably have spared amino acids from glucogenesis, thus increasing the amino acids supply available for milk protein synthesis.

Milk fat is involved in cheese yield and firmness, as well as in the color and flavor of dairy goat products (Chilliard et al. 2003). Compared with cow milk, goat milk is higher in medium-chain fatty acids (C8, C10, caprylic, and capric acids). However, cow milk is higher in butyric (C4) and, sometimes, palmitic (C16:0) acids (Chilliard et al., 2003). The lipoprotein lipase activity, although lower in goat than in cow milk, is more bound to the fat globules and better correlated to spontaneous lipolysis in goat milk (Chilliard et al., 2003). Therefore, the regulation of mammary cells differs between caprine and bovine species, particularly in the elongation process of fatty acid, which are synthesized de novo by the fatty acid synthase complex (Chilliard et al., 2003). Milk fat percentage and yield in the present study were lower for treatment D than for the concentrate supplementation groups (treatments A, B, and C). The results are in contrast to those in the literature (Bargo et al., 2003), which reported decreased milk fat percentages (6%) when cereal-based concentrates were supplemented to grazing dairy cows. However, Fernandez et al. (1997) reported that milk fat percentage was not affected by different protein levels in goats. Studies by Baldwin (1968) have shown that milk fat synthesis was derived from palmitate, and palmitate is synthesized from acetate. In our experiment, we found that acetate concentration in the rumen was highest for treatment A during the first year, and was lowest for treatment D during the second year (Table 3). One possible explanation for high milk fat percentage is that milk fat is influenced not only by concentrate level, but also by acetate concentration in the rumen.

In the present experiment, milk urea-N was higher in treatment A compared with treatments B, C, and D. Average rumen ammonia concentrations were also higher for treatments A and B than for other treatments, suggesting that grazing high quality forage and feeding different levels of concentrate altered rumen metabolites. In dairy cows fed diets containing different levels of digestible protein, milk urea-N was correlated with digestible protein intake ($r = 0.57$), ruminal protein balance ($r = 0.74$), ruminal fluid ammonia-N ($r = 0.75$), and plasma urea-N levels ($r = 0.88$; Ropstad et al., 1989). Milk urea-N can be used as a tool to monitor protein feeding efficiency, dietary protein:energy ratio, and status of animal health in dairy cows (Rajala-Schultz et al., 2001). The mean milk urea-N for dairy cows was 12.6 mg/dL (Rajala-Schultz et al., 2001), but milk urea-N in dairy goats was 18 to 22 mg/dL in the present study, and similar to that measured in another study in Alpine dairy goats (Brown-Crowder et al., 2001). Butler (1998) reported that concentrations of milk urea above 19 mg/dL have been associated with altered uterine pH and reduced fertility in dairy cows. The optimal level of milk urea-N has not been determined for dairy goats, but values for dairy goats appear to be higher than for dairy cows (Rajala-Schultz et al., 2001).

CONCLUSIONS

The present study confirmed that concentrate supply could affect milk yield and milk composition in lactating goats. However, the effect of changes in diets on milk composition is minimal compared with the effect on milk yield. Dairy goats grazing on fresh forages without supplementation can produce 3.8 kg/d. This study shows that high levels of milk production can be obtained on pasture alone, and that response to concentrate supplementation is dependent on pasture quality.

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